



Original Communication

Identification of sex in Iranian population using patella dimensions

Mitra Akhlaghi MD (Forensic Medicine Specialist, Assistant Professor),
 Ardeshtir Sheikhezadi MD (Forensic Medicine Specialist, Associate Professor)*,
 Ali Naghsh MD (Forensic Medicine Assistant), Gholamali Dorvashi MD (Forensic Medicine Assistant)

Department of Forensic Medicine, School of Medicine, Tehran University of Medical Sciences, Poursina St., Keshavarz Blvd., Tehran, Iran

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ABSTRACT

Objectives: Heretofore, sex determination has been carried out on skeletal remains to identify individuals in forensic cases and to assess populations in archaeological cases. Since it has been shown that not all bones are found in a forensic case, discriminant function equations should be derived for various bones of the body to assist in sex determination. The aim of this study was to derive discriminant function equations for sex determination from measurements of the patella.

Methods: In a prospective study, dimensions of patella were measured using the fresh cadavers of Iranian population as referred to the Tehran's Legal Medicine Organization.

Results: A total sample of 113 (57 male, 56 female) patellae were measured using three measurements. Stepwise and direct analyses were performed with the average accuracy of 92.9% for sex classification, thereby making the patella useful for sex determination.

Conclusions: The results of this study confirm the high accuracy of using the measurement of the patella for sex determination. Until further data collected suggests otherwise, the results expected in present study are limited to forensic cases of the Iranian population.

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1. Introduction

Personal identification of an individual from skeletal remains is one of the major problems in forensic medicine.¹ The first step in these cases is determination of sex, as it immediately excludes approximately half of the population.² Estimation of sex is more reliable if the complete skeleton is available for analysis but in forensic cases human skeletal remains are often incomplete or damaged. The skull, pelvis, and long bones are frequently absent or fragmented so that sex prediction must be attempted from other parts of the skeleton. However, the accuracy of sex estimation from other skeletal elements depends on the degree of sexual dimorphism exhibited by the skeleton.³

Generally, there are two methods for sex determination from skeletal remains: morphologic and metric studies. The morphologic method involves the observation of sexual traits on bones such as wide sub pubic angle in females. This method is quicker

but will have accurate results if the observer has enough experience. On the other hand, the metric method is based on measurements and statistical techniques which doesn't require expertise and can be repeated to validate results.⁴

Physical anthropology has traditionally employed both qualitative and quantitative strategies to estimate sex from skeletal remains, but due to its variable nature, osteometric method has often been deemed more reliable.⁵

One of the skeletal elements drawing more attention recently is the patella. Patella, the largest one of the sesamoid bone is situated in front of the knee joint in the tendon of the quadriceps femoris. It is flattened and triangular and has an anterior and posterior surface, three borders, and an apex.³ The kneecap is a solid element of the human skeleton with no discernible morphological features for determining sex and no significant differences attributed to race. However, as a sesamoid bone that forms within the tendon of the quadriceps muscle, it is very resistant to postmortem changes and so available for personal identification purposes.⁶ Although the patella is very resistant to the decomposition process it is also one of the bones most often lost at the crime scene (due to animal activity and incomplete recovery).

There are a few studies about determination of sex from patella. The first was made by McWilliam and El Najar in 1978.⁴ They used volumetric analysis with submerging the patella into container of

* Corresponding author. Address: Department of Forensic Medicine, Faculty of Medicine, Tehran University of Medical Sciences, Poursina St., Keshavarz Blvd., Tehran 1417613151, Iran. Tel.: +98 21 22126039, mobile: +98 912 2890395; fax: +98 21 66405588.

E-mail addresses: ardeshirsheikhezadi@yahoo.com, sheikhezadi@tums.ac.ir (A. Sheikhezadi).

water and using the displacement method in calculating the volume of the bone. Most of the male patellas were more than 15 cc and the female were less than 11 cc.⁴

Introna et al. used 80 right patella belonging to the southern Italian population whose time of their death was around 1970 and ages ranged from 25 to 80 years. In univariate discriminant analysis thickness and height of facies art exterior were the parameters with the highest autonomous percentage of correct classification (78.8% each one). Also in multivariate discriminant analysis maximum width and thickness together showed the highest percentage of correct sex determination (83.8%).⁷

In the next study, Kemkes-Grottenthaler used 82 patellas from three groups and measured seven variables. Male values always exceeded female values in all observed dimensions. In univariate discriminant analysis maximum height achieved the highest percentage of correct classification (80.8%).⁵

Bidmos et al. examined 120 patellas of South African whites. They found male values exceeding the females. In univariate discriminant analysis maximum height and then maximum width were the best variates for sex determination (85% and 79%, respectively), and in multivariate discriminant analysis the best function was to use all dimensions together (average accuracy 85%).⁸

Finally, Dayal and Bidmos in South African blacks studied 120 patella using the same measurements previously employed by Bidmos. The average accuracy percentage of maximum breadth was the highest (80%) with demarking point (dp) for males >41.16 and females <41.16 mm.⁹

As the patella is very resistant to postmortem changes, the present study aims to estimate the sex of Iranian individuals on the basis of osteometric methods of patella bone. The usefulness of this trait is further enhanced by the fact that this sesamoid has great survivability in the archaeological context. The purpose of the present study is to investigate the usefulness of the patella method when applied as a single sex-indicator. The investigation was also designed to provide insights into possible confounding factors. We present multivariate analysis on patella measurements taken from a fresh deceased's collection of the contemporary Iranian population whose sex, age and time of death were known.

2. Materials and methods

The study was carried out on fresh Iranian corpses whose ages were >19 Y/O and were referred to the Legal Medicine Organization (LMO) of Tehran,^{10,11} Iran during 20 months from 1st January 2007 to 1st September 2008.

Iranian corpses being citizen of Tehran were chosen with intact right patella, since in other researches, no statistically significant differences between right and left patella revealed.¹² Cases which for any reason could not be measured for parameters of patella or could not be defined for age or sex were excluded from the study. According to the classification of WHO corpses were classified in three groups, young (20–39 years), middle aged (40–64 years) and old age (≥65 years). We considered at least 15 men and 15 women from each groups.

This volume sample was calculated according to previously published literature by using the formula¹³:

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 (\sigma_1^2 + \sigma_2^2)}{(\mu_1 - \mu_2)^2} \quad \alpha = 0.01, \quad \beta = 0.1$$

μ_1 , μ_2 and σ_1 , σ_2 for each variable are different on the basis of the study.

In this study three metrical characteristics were taken from each patella, because previous studies emphasized these three parameters as the most useful sex differentiating parameters:

Maximum height: maximum linear distance between the tip of apex and the base.

Maximum width: maximum linear distance between the medial and lateral borders.

Maximum thickness: maximum distance between the anterior and posterior surface.

After obtaining a written consent from first degree relatives of the deceased, longitudinal incision of skin from superior to inferior portion of right knee was made and then tendon of quadriceps was cut from its insertion. Then patella and tendon turned so that the posterior aspect of patella was exposed. As the amount of cartilage and soft tissue in apex and base of patella is very little, these were easily scraped, so we could measure maximum height of patella. Then at the site of maximum width we cut the patella with orthopedical saw vertically (Fig. 1).

Thus we could measure both maximum thickness and maximum width without inconvenience of soft tissue and cartilage. Measurements were taken by forensic medicine professional assistants and supervised by one of the authors. After measurement of patella parameters, patella was set in its place and skin was repaired. In all stage of autopsy dignity of corpses was considered. Age and sex in addition to patella parameters were recorded in questionnaires.

The statistical product and service solution program (SPSS 16) was used to analyze all data. Descriptive statistics which included mean, standard deviation, minimum and maximum were obtained for all variables. After establishing that significant difference exists between male and female mean values for each parameters, *f* statistics, univariate and multivariate discriminant function analysis were performed with SPSS 16.

3. Results

Three anthropometric parameters of patella from 113 corpses being referred to autopsy hall of Tehran's LMO were measured. All deceased were >19 Y/O.

Fifty-seven cases were male (50.45%) and 56 cases were female (49.55%). Corpses from each sex divided to three age groups: Group A: Young (35 cases, 30.99%); Group B: Middle age (32 cases, 28.32%); Group C: Old age (46 cases, 40.71%). The frequency of cases of each group according to the sex is shown in Table 1.

The results of descriptive statistical analysis are reported in Table 2. The mean of patella height in all corpses was 4.16 cm (SD = 0.40), minimum of 3.42 and maximum 5.13 cm. Mean of patella height was 4.47 cm (SD = 0.27) in males and 3.83 (SD = 0.20) in females. Minimum of patella height was 3.88 in males and 3.42 cm in females. Maximum of patella height was 5.13 in males and 4.53 cm in females.

The mean of patella width in all corpses was 4.28 cm (SD = 0.34) with minimum of 3.55 and maximum 5.10 cm. Mean of patella width was 4.55 (SD = 0.22) in males and 4.01 (SD = 0.19) in females, minimum of patella width was 4.10 and 3.55 in males and females respectively. Maximum of patella width was 5.10 in males and 4.50 cm in females.

The mean of patella thickness in all corpses was 2.11 (SD = 0.18) with minimum 1.60 and maximum 2.60 cm. Mean of patella thickness was 2.19 (SD = 0.19) in males and 2.03 (SD = 0.14) in females. Minimum of patella thickness was 1.76 and 1.60 cm in males and females respectively. Maximum of patella thickness was 2.60 cm in males and 2.38 cm in females.

For statistical analysis of data, normality of parameters' distribution was assessed with Kolmogorou Smirnov test (Lillie Force significance collection). Thickness in Groups A and B and width in all groups had normal distribution. Analysis of these param-



Fig. 1. Measuring of the patellar width.

Table 1
The frequency of cases of each age group according to the sex.

Age groups	Frequency [n (%)]		
	Males	Females	All
Group A: Young	18 (31.6)	17 (30.5)	35 (31.0)
Group B: Middle aged	17 (29.8)	15 (26.7)	32 (28.3)
Group C: Old age	22 (38.6)	24 (42.8)	46 (40.7)
Total	57 (100.0)	56 (100.0)	113 (100.0)

ters was done by independent sampling test. Thickness in Group C and height in all groups did not have normal distribution, so analysis of those was done by Mann Whitney test (Non-parametric test).

When males and females were compared, mean of height and mean of width values in all age groups showed significant differ-

ence ($p = 0.000$). Also mean of thickness value in Groups A–C showed significant statistical difference between males and females ($p < 0.003$, $p < 0.023$, $p = 0.000$, respectively).

After observation of significant difference in all dimensions of patella between males and females, we achieved a demarking point for all dimensions of the patella. Demarking point indicates a number which less than it suggests female and more than it suggests male. This indicator was calculated by using average of mean numbers of each of patella dimensions in males and females. Thus dp was calculated in all cases as following: 4.16 cm, 4.28 cm and 2.11 cm for maximum height, maximum width, and maximum thickness respectively.

Then with regard to demarking point in total cases and each of the age groups for prediction of average accuracy in each of the patella dimensions, univariate discriminant function analysis was performed for sex discrimination. Also using the multivariate dis-

Table 2
The results of descriptive statistical analysis of patella measurements (cm).

Patella parameters	Age group (years)	19–39			40–64			≥65			Total		
		Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Height	Mean	4.5044	3.8200	4.1720	4.42	3.94	4.19	4.49	3.78	4.12	4.47	3.837	4.158
	SD	0.2059	0.1565	0.3914	0.31	0.25	0.37	0.30	0.18	0.43	0.27	0.20	0.40
	Min.	4.10	3.50	3.50	3.88	3.50	3.98	3.98	3.42	3.42	3.88	3.42	3.42
	Maximum	4.89	4.16	4.89	5.13	4.53	5.13	5.00	4.28	5.00	5.13	4.53	5.13
Width	Mean	4.61	3.96	4.29	4.59	4.10	4.36	4.47	3.99	4.22	4.55	4.01	4.28
	SD	0.18	0.18	0.37	0.26	0.17	0.33	0.20	0.20	0.31	0.22	0.19	0.34
	Minimum	4.30	3.55	3.55	4.10	3.82	3.82	4.10	3.68	3.68	4.10	3.55	3.55
	Maximum	5.04	4.25	5.04	5.10	4.50	5.10	4.90	4.42	4.90	5.10	4.50	5.10
Thickness	Mean	2.27	2.10	2.188	2.23	2.04	2.14	2.11	1.97	2.03	2.19	2.03	2.11
	SD	0.14	0.17	0.17	0.26	0.16	0.24	0.10	0.06	0.11	0.19	0.14	0.18
	Minimum	2.08	1.70	1.70	1.76	1.60	1.60	1.82	1.78	1.78	1.76	1.60	1.60
	Maximum	2.60	2.36	2.60	2.60	2.38	2.60	2.24	2.10	2.24	2.60	2.38	2.60

Table 3

Demarking points for sex differentiation by using the patella dimensions.

Age groups	Measurement	Demarking points (cm)	Average accuracy (%)
A	Maximum thickness	Females < 2.19 < males	65.85
	Maximum height	Females < 4.16 < males	97.20
	Maximum width	Females < 4.29 < males	100.0
	Total		100.0 (for males) 89.7 (for females)
B	Maximum thickness	Females < 2.13 < males	71.95
	Maximum height	Females < 4.18 < males	84.55
	Maximum width	Females < 4.35 < males	87.85
	Total		88.2 (for males) 93.3 (for females)
C	Maximum thickness	Females < 2.03 < males	80.4
	Maximum height	Females < 4.12 < males	89.1
	Maximum width	Females < 4.22 < males	89.1
	Total		90.9 (for males) 95.8 (for females)
Total	Maximum thickness	Females < 2.11 < males	74.3
	Maximum height	Females < 4.16 < males	89.4
	Maximum width	Females < 4.28 < males	91.2
	Total		92.9 (for males and females)

criminant function analysis the average accuracy was calculated for same values (maximum height, maximum width, and maximum thickness) in all cases.

If only thickness was considered, accuracy in cross validated and accuracy in original group for all cases was 74.3%, if only width was considered accuracy for all cases was 91.2%, if only height was considered accuracy in all cases was 89.4%, and when all three measurements were considered the accuracy was 92.9% (Table 3).

In Group A: if only thickness was considered (dp: 2.19) accuracy in cross validated and accuracy in original group was 65.85%, if only width was considered (dp: 4.29) accuracy was 100%, if only height was considered (dp: 4.16) accuracy was 97.2% and when all three measurements were considered, the average accuracy for correct sex classification was 94.85% (Table 3).

In Group B: if only thickness was considered (dp: 2.13) accuracy in cross validated and accuracy in original group was 71.95%, if only width was considered (dp: 4.35) accuracy was 87.85%, if only height was considered (dp: 4.18) accuracy was 84.55% and when all three measurements were considered the average accuracy for correct sex classification was 90.75% (Table 3).

In Group C: if only thickness was considered (dp: 2.03) accuracy in cross validated and accuracy in original group was 80.4%, if only width was considered (dp: 4.22) accuracy was 89.1%, if only height was considered (dp: 4.12) accuracy was 89.1% and when all three measurements were considered the average accuracy for correct sex classification was 93.5% (Table 3).

Finally using the multivariate discriminant analysis, combination of all three measurements with average accuracy of 92.9% was the best value for sex determination without consideration of age.

4. Discussion

Measurements taken on most bones in the body have shown higher mean values for males compared to females. The patella follows a similar pattern.^{8,13}

In our study the mean of patella height in males was 4.474 cm and in females 3.837 cm, the mean of width in males was 4.552 cm and in females 4.013 cm and the mean of thickness in males was 2.195 cm and in females 2.029 cm. Among these measurements maximum width with average accuracy of 91.2% and then maxi-

imum of height with average accuracy of 89.4% and finally maximum of thickness with average accuracy 74.3% were respectively best variables for sex determination. For example, measuring maximum width of a patella bone and comparing it to demarking point (4.28 cm) can determine sex with 91.2% accuracy. Also with multivariate discriminant analysis combination of all three measurements with average accuracy of 92.9% would be the best value for sex determination.

In our study, the average accuracy of sex determination by using the maximum thickness of patella without consideration of age was 74.3%. Whereas this value in different age groups including young (65.85%), middle aged (71.95%) and old age (80.4%) had a progressive course.

The average accuracy of sex determination by using the maximum height of patella, without consideration of age was 89.4%. Whereas this value in different age groups including young (97.2%), middle aged (84.55%) and old age (89.1%) had a fluctuating course.

The average accuracy of sex determination by using the maximum width of patella without consideration of age was 91.2%. Whereas this value in different age groups including young (100.0%), middle aged (87.85%) and old age (89.1%) had a fluctuating course.

Nevertheless, average accuracy of sex determination by each of the measurements of patella in all age groups is high and relatively similar. Although the average accuracy of sex determination by using the maximum thickness of patella was increasing with age, there was not a similar course about other dimensions of patella. Its explanation may be due to role of other variables such as ethnic and geographical factors. Although the study was done on Tehran's residents, they were not necessarily from the same ethnicity and might have had origins from other parts of Iran. Thus it seems that more studies must be done in different parts of the country.

However with regard to average accuracy of sex determination by each measurements of patella in different age groups, although there are some differences, the variations are scanty.

This study which is the first on the patellas of recent dead persons confirms the results of the past studies on the patellas of bone collections. But there are a few differences.

In literature review, there are a few studies about determination of sex from patella and all of them were done on skeletal remains. We did not find any study performed on fresh cadavers in various age groups. Summary of findings of our study compared to previous studies are shown in Table 4.

Compared with the study of Introna et al.⁷ our means in all 3 variables in both sexes were higher, also in that study maximum thickness with average accuracy of 78.75% was the best variable for sex determination and then maximum width and height of facies articularis ex were the best. Whereas in our study maximum of width was the best variable (91.2%). With multivariate discriminant analysis the best function of their study was a combination of maximum of thickness and width with 83.8% accuracy. While the best function of their study was a combination of three dimensions of patella with 92.9% accuracy for sex determination.

Compared with the study of Kemkes-Grottenthaler⁵ except for the mean of patella height in females and mean of patella width in males, our measurements were higher. In their study maximum accuracy belonged to maximum of height (80.8%) and then maximum of width and thickness with 76.9% average accuracy. Combination of height of facies articularis interior and height of facies articularis exterior had 100% accuracy in sex determination.

As compared with Bidmos et al. study,⁸ except the mean of height and width of patella in females, our measurements were higher. In their study maximum of height with average accuracy 85%, maximum of width with 79.2% and maximum of thickness

Table 4

Comparison of different studies were done on patella dimensions for sex discrimination.

Study	Our study								Introna		Grottenthaler		Bidmos		Dayal	
	20–39 years		40–64 years		Over 64 years		Total		M	F	M	F	M	F	M	F
Parameter	M ^a	F ^b	M	F	M	F	M	F								
Mean of height	4.50	3.82	4.42	3.94	4.48	3.78	4.47	3.83	4.12	3.70	4.38	3.95	4.36	3.84	4.12	3.64
Mean of width	4.60	3.94	4.59	4.10	4.47	3.98	4.55	4.01	4.32	3.94	4.59	3.98	4.53	4.33	4.23	3.89
Mean of thickness	2.27	2.10	2.22	2.03	2.10	1.97	2.19	2.03	2.04	1.83	2.05	1.82	2.38	1.83	2.56	1.82
Maximum height average accuracy	97.20		84.55		89.10		89.4		71.25		80.8		85		79.2	
Maximum width average accuracy	100		87.85		89.10		91.2		72.50		76.9		79.2		80.04	
Maximum thickness average accuracy	65.5		71.95		80.4		74.3		78.75		76.9		75.8		77.5	
Total maximum accuracy	100	89.7	88.20	93.3	90.9	95.8	92.9	92.9	83.8		84.6		85		83.5–85	

^a M: male.^b F: female.

with 75.8% were the best variations of all measurements. They were the best function for sex determination respectively. With multivariate discriminant analysis combination of all measurements was the best function for sex determination with average accuracy of 85%.

Finally our measurement compared with the study of Dayal and Bidmos⁹ were higher too, except the mean of patellar thickness in males. In their study the maximum accuracy belonged to maximum of width (80%), then maximum of height (79.2%) and finally maximum of thickness (77.5%). Combination of these variables resulted in 85% accuracy in sex determination.

Overall, our study which was the first research on the patellas of fresh cadavers confirms the results of the past studies on the patellas of bone collections and skeletal remains. All measurements of patella dimensions in males were higher than females. But our findings were greater than the measurements taken on the patellas of bone collections and skeletal remains.

We are aware that patterns of sexual dimorphism vary among populations and that the functions obtained could not have a similar accuracy if applied to different ethnic groups from the Iranian population. Nevertheless the results of this study confirm the accuracy of the patella for sex determination and it may be the best discriminant function reported and considered a valid support in forensic investigations involving skeletal remains.

These functions can be applied to a special set of circumstances when skeletal sex determination must be obtained using only patella samples because no other portion which might be useful in sex determination is present or adequately preserved (i.e. multiple human burials, mass disasters, air crashes, etc.). We think our method would be useful when we just have the legs etc., but it would be worth highlighting that it would be useful even in cases of complete skeletal recovery as another method to help determining sex. Legal Medicine Organization of Iran with about 1.5 million forensic referrals and 50000 autopsies per year is an appropriate field for such research and training.^{14–19}

5. Conflicts of Interest

None declared.

6. Funding

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7. Ethical Approval

Written informed consent was obtained from the bereaved family of every patient prior to the autopsy examination. The ethical consideration was approved by the Ethics Committee of the Research Deputy of Iran's Legal Medicine Organization.

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